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AUTHOR Schlenker, Richard M.
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ABSTRACT

This document presents a series of physics experiments which allow students to determine the value of unknown electrical capacitors. The exercises include both parallel and series connected capacitors. (SL)

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A LABORATORY EXERCISE IN PHYSICS: DETERMINING SINGLE CAPACITANCES AND SERIES AND PARALLEL COMBINATIONS OF CAPACITANCE

BY

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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RICHARD M. SCHLENKER
DEPARTMENT OF ARTS AND SCIENCE
MAINE MARITIME ACACEMY
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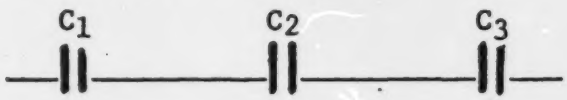
ABSTRACT

The student ascertains the values of various unknown individual capacitors as well as series and parallel combinations of unknown capacitors. This is accomplished by comparing a galvanometer deflection caused by a known capacitor with that caused by one or more unknown capacitors. The exercise is designed to develop the concepts of series and parallel capacitance, to develop observational skills, and to provide experience in manipulating and reporting data.

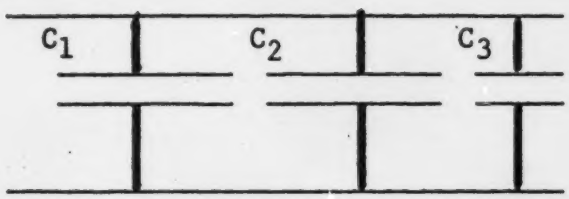
INTRODUCTION

Capacitors are used to perform a variety of functions in electrical and electronic circuits. They are used to prevent contract arcing, to select wanted radio frequencies, to store electrical charges, and so on ad infinitum. Some applications use capacitors wired in a series configuration while other applications use them in a parallel configuration. Finally, there are some applications which require that capacitors be wired to a series-parallel configuration.

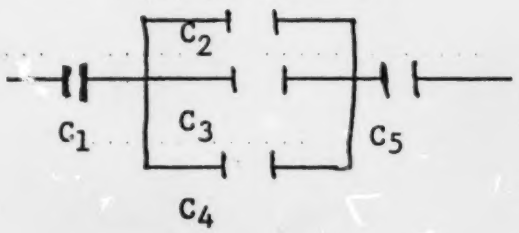
SERIES CONFIGURATION



PARALLEL CONFIGURATION



SERIES-PARALLEL CONFIGURATION



The type of configuration determines the total amount of capacitance which is presented to the circuit. Total capacitance in a series configuration may be computed using the formula;

$$\frac{1}{C_{TOTAL}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

total capacitance in a parallel circuit may be computed using the formula;

$$C_{TOTAL} = C_1 + C_2 + C_3$$

It follows then that total capacitance in the series-parallel configuration is mathematically ascertained by combining the series and parallel formulas. In the model series parallel configuration shown above, the total capacitance is;

$$\frac{1}{C_{TOTAL}} = \frac{1}{C_1} + \frac{1}{(C_1+C_2+C_3)} + \frac{1}{C_5}$$

where $(C_1 + C_2 + C_3)$ = the capacitance of the parallel branch.

OBJECTIVES

The objective of this laboratory is to:

1. Determine the values (in capacitance) of single unknown capacitors.
2. Determine the total capacitance of capacitors wired in series.
3. Determine the total capacitance of capacitors in parallel.

DISCUSSION

The objectives of this exercise are accomplished by comparing unknown capacitors with a standard capacitor (a standard capacitor is one whose value is known), while holding a source voltage constant. The value of the known capacitor in this exercise is one microfarad (1 uf). In order to accomplish this task, we will use a device called a galvanometer.

The capacitance (of a capacitor) is defined as the ratio of the charge to the potential difference or capacitance is equivalent to the charge on the plates of the capacitor divided by the difference in potential between the plates:

CAPACITANCE (IN FARADS) = Q(IN COULOMBS)/V(IN VOLTS)

The capacitance of the standard capacitor then is:

$$C_{STANDARD} = Q_{STANDARD}/V_{STANDARD}$$

and

$$V_S = Q_S/C_S \quad \text{where S = STANDARD}$$

The same relationships hold for unknown capacitors:

$$C_{UNKNOWN} = Q_{UNKNOWN}/V_{UNKNOWN} \quad \text{and}$$

$$V_X = Q_X/C_X \quad \text{where X = unknown}$$

It was mentioned previously that throughout the conduct of the investigation, voltage is held constant. Therefore, the difference in potential across the plates of the standard capacitor will be equivalent to that across the plates of the unknown capacitor or:

$$V_S = V_X$$

and since quantities equal to the same quantity are equal to each other, we may substitute

$$Q_S/C_S \text{ for } V_S \quad \text{and} \quad Q_X/C_X \text{ for } V_X$$

It follows that:

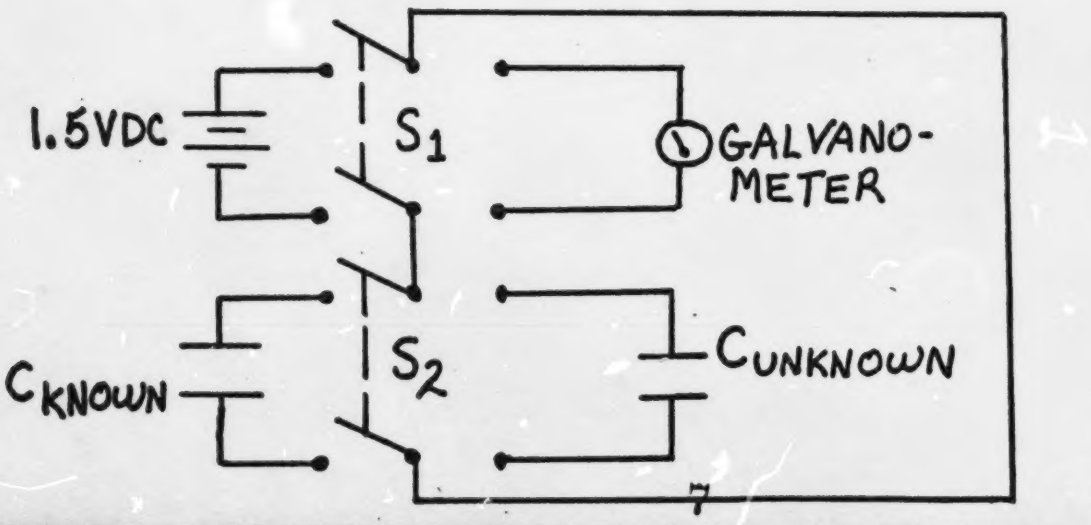
$$Q_S/C_S = Q_X/C_X \text{ and } C_X/C_S = Q_X/Q_S$$

We use a galvanometer in this laboratory which has a sighting slot and two scales. A capacitor is charged, and then discharged through the galvanometer. When discharge occurs, a coil in the galvanometer is caused to move. This movement can be seen by observing the relative movement of one of the scales as observed through the sighting slot.

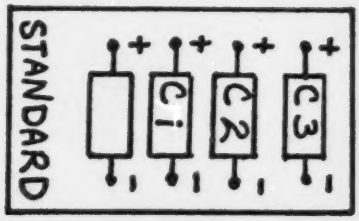
For a given voltage, the amount of relative deflection is proportional to the magnitude of the charge on the plates. This deflection is really a distance (D). It follows then that the deflection caused by the charge on an unknown capacitor is proportional to the amount the galvanometer is deflected when the capacitor is allowed to discharge. Therefore, D_S or deflection of the standard and D_X, the deflection of the unknown, may be substituted for Q_S and Q_X respectively in the equation,

$$C_X/C_S = Q_X/Q_S \text{ and so } C_X/C_S = D_X/D_S$$

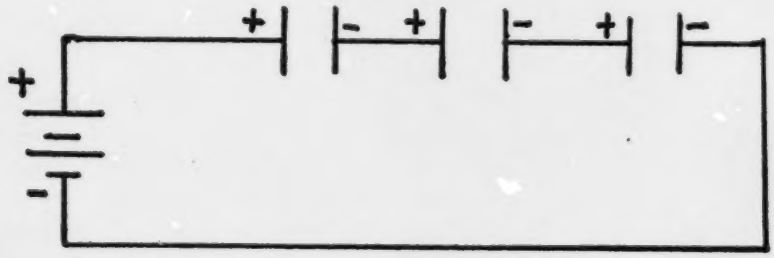
The circuit used in the investigation appears schematically as follows:



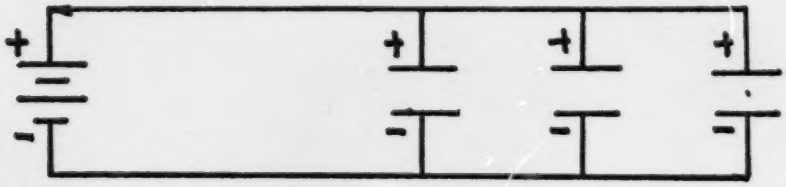
and the board holding the capacitors physically appears as:



where C_1, C_2, and C_3 are unknown capacitors. In addition, note that polarities have been indicated. This has been done since the capacitors used in the investigation are electrolytic and electrolytic capacitors are polarity sensitive. When the capacitors are wired in a series configuration, they should appear as follows:



and when in parallel they should appear as:



PROCEDURES

1. Ascertain the amount of galvanometer deflection caused by applying a potential of 1½ volts across the plates of the standard capacitor. This is accomplished by closing the switch so that the standard is allowed to charge (allow about a minute). Then change the position of the switch and allow the standard capacitor to discharge through the galvanometer. You should note the amount the galvanometer is deflected.

2. Repeat step one only this time using each of the unknown capacitors (C_1, C_2, and C_3).You will have to rewire the capacitor board in order to accomplish this step.

3. Repeat step one only this time, wire the unknown capacitors in a series configuration (the unknowns are electrolytic capacitors and therefore polarity sensitive therefore it is necessary to wire the positive plate of the first capacitor to the positive pole of the battery, then the negative pole of this capacitor should be wired to the positive pole of the second capacitor, etc.).

4. Repeat step one only this time wire the capacitors in a parallel configuration. This can be accomplished by wiring all of the positive plates together and wiring all of the negative plates together (again, the capacitors are polarity sensitive).

5. Evaluate your data and write a report of your investigation. What happens to C when capacitors are wired in series? What happens to C when capacitors are wired in parallel?

Your report should be divided into the following sections: Introduction; Methods; Data; Discussion; and Conclusions.

In your evaluation of your data you should mathematically compute the series and parallel capacitances based upon your measurement of the individual capacitances. Then compare this figure with the series and parallel combinations obtained using the galvanometer.